New Method Developed for Aeroelastic Stability Analysis

The development of advanced-design ultrahigh bypass ratio engines has led to renewed interest in the study of the flutter of bladed disks. Previously, two fundamental approaches were used in flutter calculations: frequency domain analysis and time-domain analysis. With the development of time-marching computational fluid dynamics (CFD) flow solvers, both approaches have been used with equal ease. In the present work at the NASA Lewis Research Center, substantial computational savings have been achieved by applying a numerical eigensolver to a nonlinear, time-marching fluid-structure interaction system solver for flutter prediction.

The numerical eigensolver works with the steady-flow solution to determine the eigenvalues and eigenmodes corresponding to the fluid-structure interaction system directly. It does not require a time history of forces on blades and subsequent Fourier transformation to determine stability. Also, it avoids computationally expensive time-domain simulations of small perturbation responses, where several cycles of oscillation are required to determine the growth or decay of perturbations. With this new method, the computational savings over the existing frequency and time-domain nonlinear methods are of the order of 100 to 10,000. However, note that fundamentally this is a small perturbation (linear) aeroelastic analysis, although steady-flow nonlinearities are taken into account (e.g., blade thickness, blade camber, and shock waves).

In the present work, a numerical eigensystem solver, based on a Lanczos procedure, is applied to a two-dimensional, full-potential, cascade aeroelastic solver. Calculations are performed for a cascade geometry used in previous research. Frequency- and time-domain flutter calculations were previously performed for this configuration. The steady solution is first obtained, as required in all such calculations. Then, the numerical eigensystem solver is used to calculate eigenvalues.

The eigenvalues obtained from this new approach indicate whether the aeroelastic system is stable or unstable. A comparison of the results from this approach with those from existing flutter determination methods shows that the new approach predicts the correct flutter condition. It shows good agreement in flutter speed and flutter mode.

The numerical eigensystem analysis results in substantial computer time savings in comparison to the frequency- and time-domain solutions. It will allow the use of nonlinear, time-marching solvers in routine aeroelastic design analysis. Because of the modular nature of the numerical eigensystem solver, it can be readily adapted to other time-marching aeroelastic solvers with minimal additional effort required on the researchers' part.

SAMPLE FLUTTER RESULTS FROM FULL-POTENTIAL AEROELASTIC CODE*

Flutter parameter	Frequency domain	Time domain	New method

Frequency	0.265	0.262	0.239
Velocity	13.35	13.45	13.65

*All values are nondimensional.

Bibliography

Mahajan, A.J.; Bakhle, M.A.; and Dowell, E.H.: A New Method for Aeroelastic Stability Analysis of Cascades Using Nonlinear, Time-Marching CFD Solvers. AIAA Paper 94-4396, 1994.